Progress on Spent Fuel Data Compilations for PWRs

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Outline

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III. **Summary and conclusions**

INDUSTRIALES
ETSII | UPM

Objectives and description of SFCOMPO / UPM collaboration

- A "*Collaborative Agreement"* involving the **collective participation of our students** in their last year of our "*Nuclear Engineering Master Degree Programme"* for: "*the review and capturing of selected spent fuel isotopic assay data sets to be included in the new SFCOMPO database*".

- **SFCOMPO / UPM Collaboration**: (F. Michel-Sendis visited Madrid, April 25th, 2013)
  - Data capturing
  - Data verification
  - SFCOMPO Tool functionalities "beta testing"
  - Feedback :
    - *Required developments*
    - *"Template Format testing"*
    - *Uniformization / conversion of units*
  - Agenda: May-July 2013
  - NEA Data Bank financial support for this task

Nuclear Energy Education at UPM

- **Industrial Engineering (Energy/Nuclear Branch)**
  ABET (Accreditation Board for Engineering and Technology) in 2010
- **Master in Nuclear Science and Technology**
  Mention of Quality & with the verification of General Direction of Universities
- **Master in Energy Engineering (Nuclear Branch)**
- **Master in Technologies for Electrical Power Plants**
  (DIN&ETSIIM&Tecnatom)

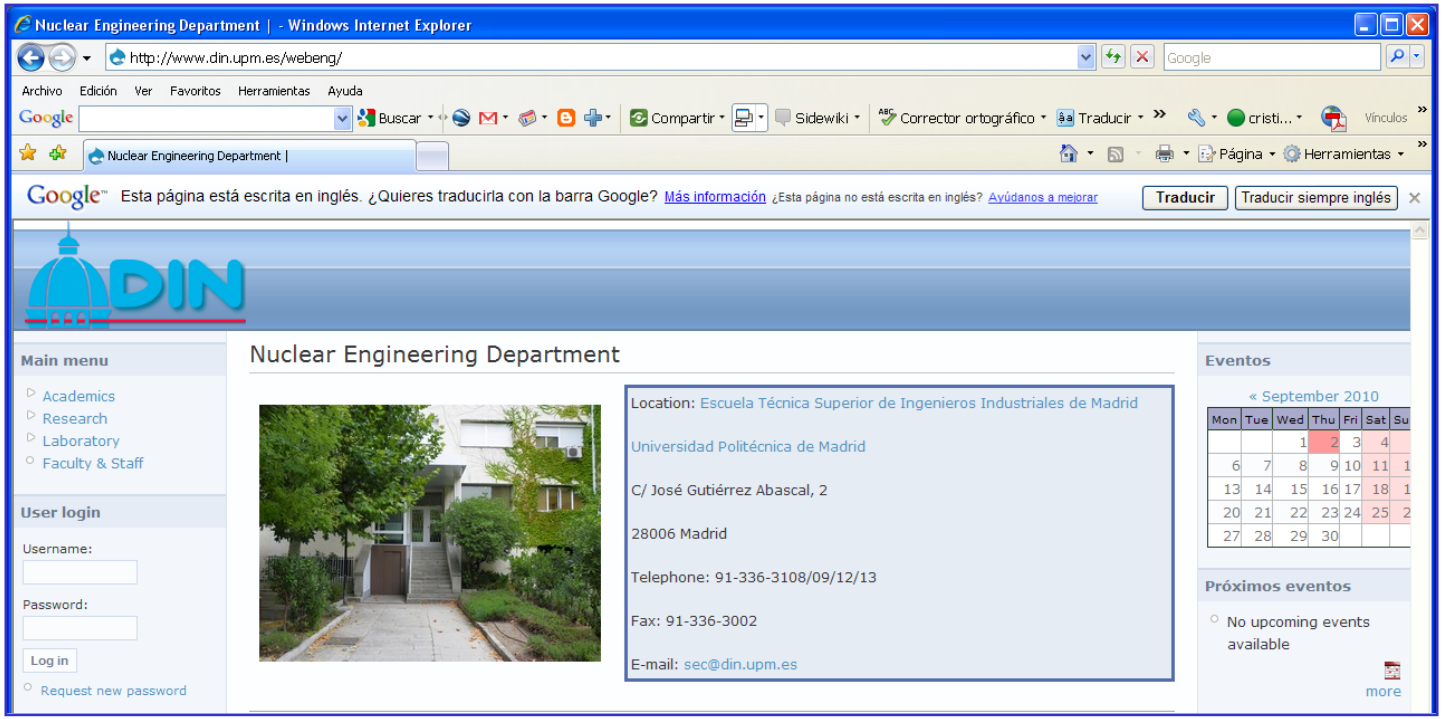


Figure 1: Nuclear Engineering Department

Web site:
(*www.din.upm.es*)

SFCOMPO / UPM – Students
Course: "Nuclear Reactor Design"

- **We have introduced current computational methodologies and codes for reactor nuclear designs**

  For students, the understanding in a comprehensive way of these codes (JANIS, NJOY, WIMSD, MCNP, ORIGEN/ACAB, COBRA-TF, SEANAP, …) is an important value in simulation, design and advanced analysis both in the research activities and in the professional work

- **Methodology: "working in group"**
  - **Classes:** 14 weeks; 5hours/week
  - **15/20 students/year**
  - **Documentation:**
    - Theory and tests
    - Code User's Manual
    - Hands-on work
  - **Extra seminars:**
    - J.C. Kuijper (2007)
    - R. Sanchez (2008)
    - Ivo Kodeli (2008)
    - Kostadin Ivanov (2009)
    - Enrico Sartori (2010)
    - Roberto Capote (2010)
    - J.C. Neuber (2011)
    - Y. Rugama (2012)
    - I. Gauld (2013)
    - …

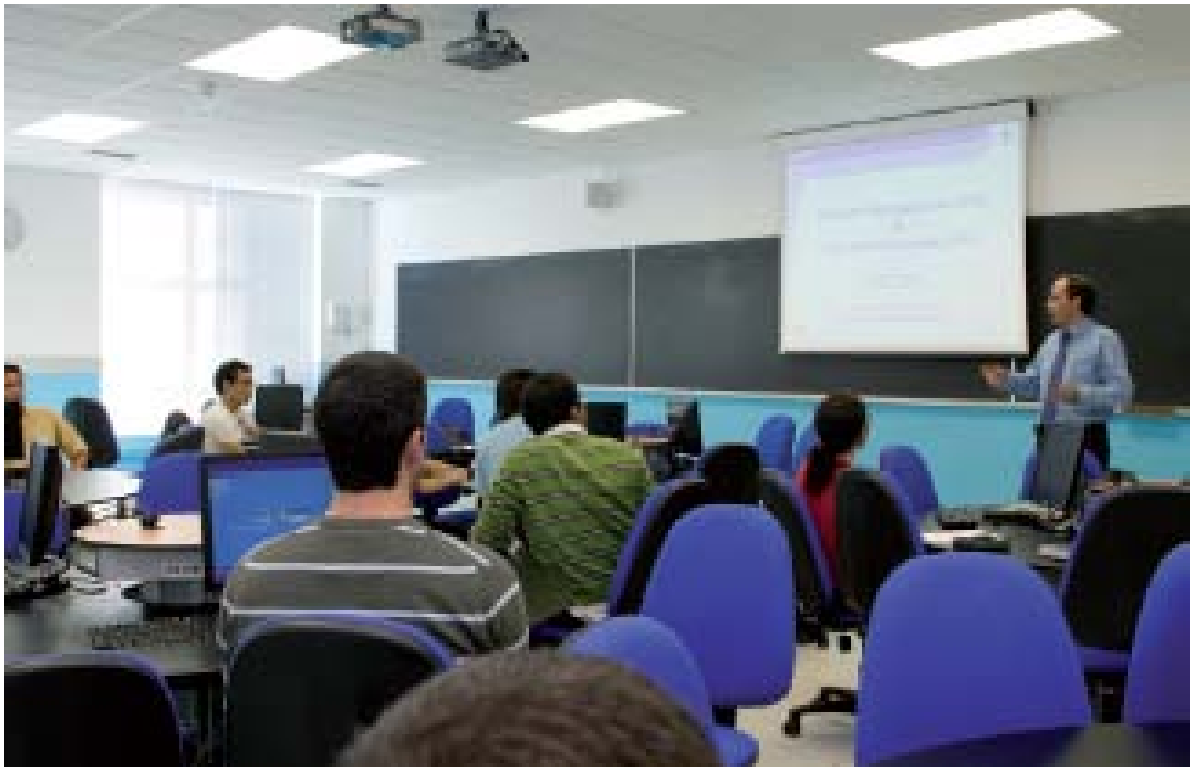
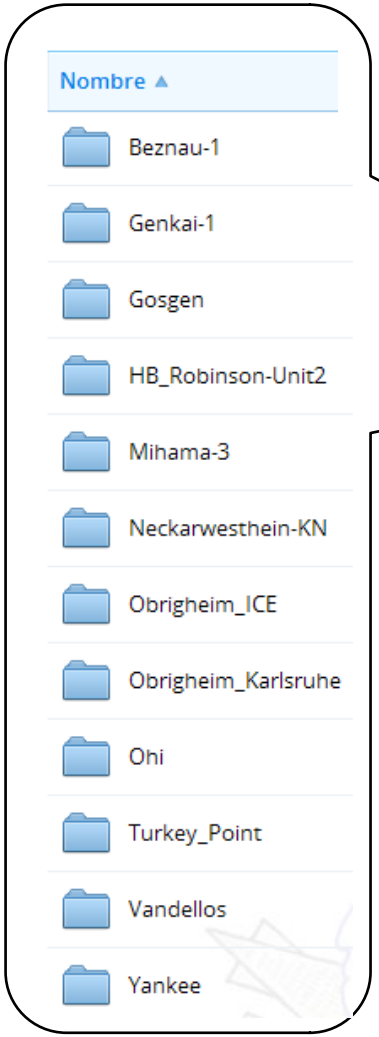
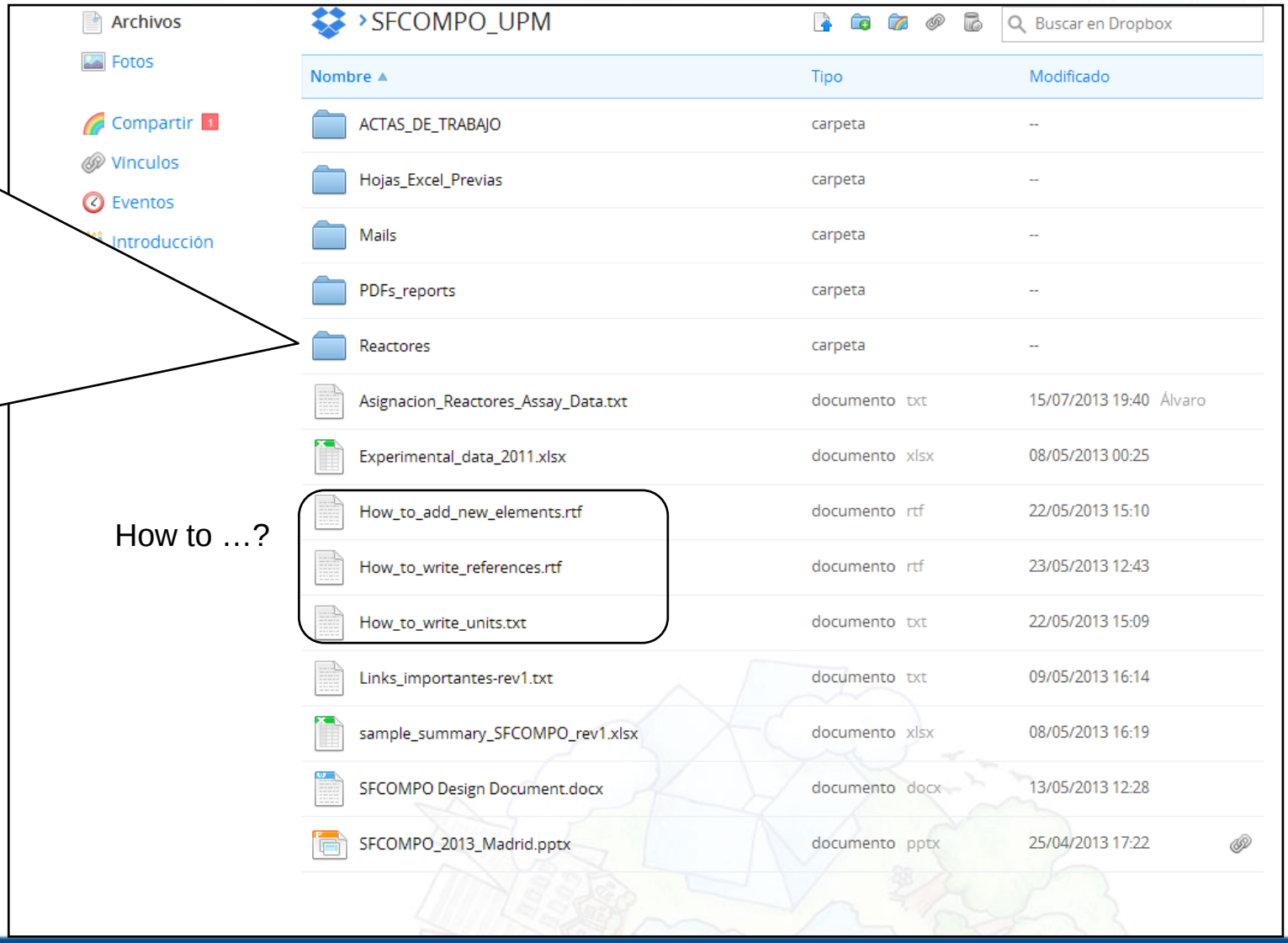


Figure 2: Classroom picture

DROPBOX: "shared area by students"



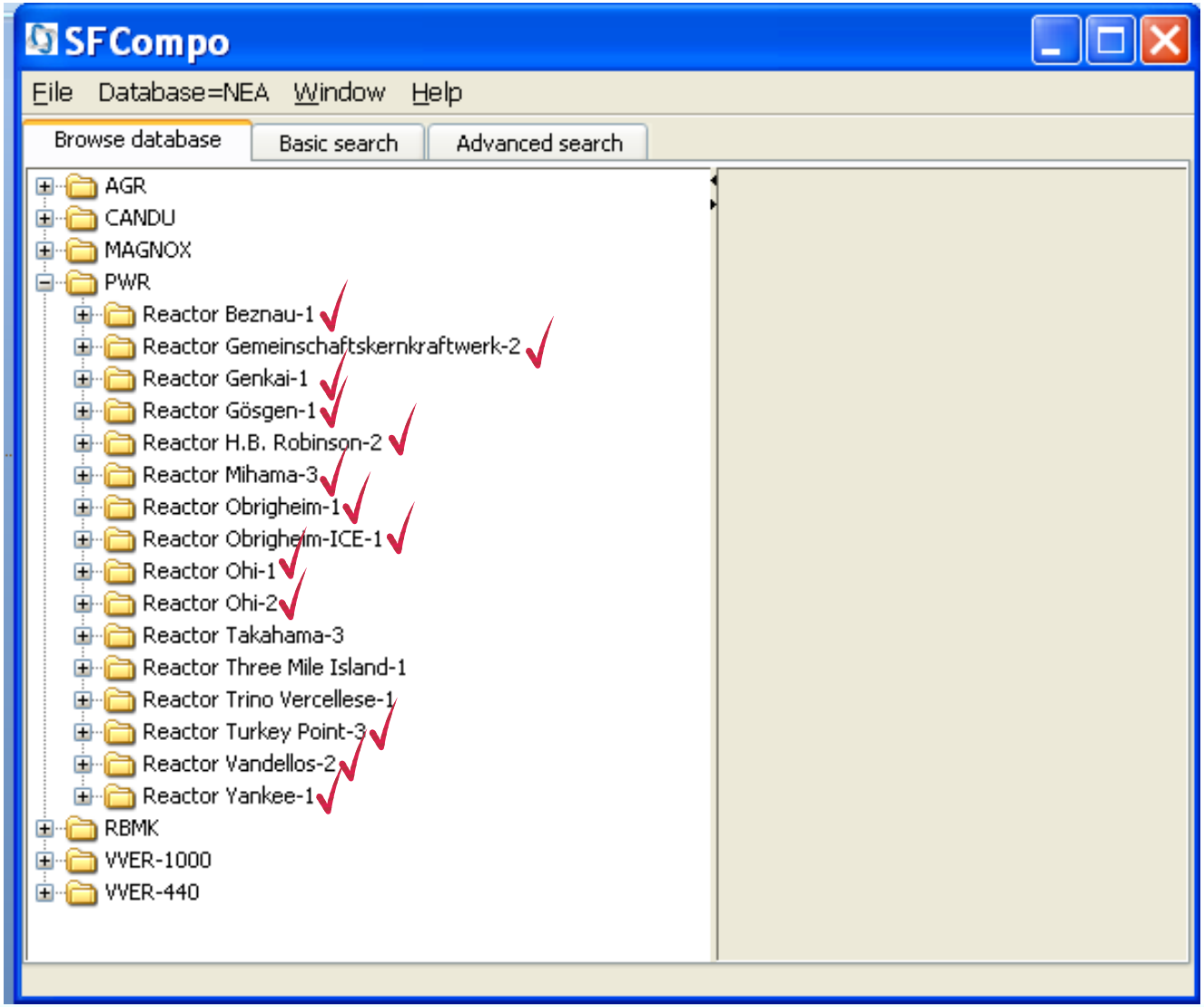


How to …?

Reactor and Review Assignments

ALUMNO	1st Task:"Reactor Assignment"	2nd Task: "Review Assignment"
1) R. Ruiz	Ohi	H.B.Robinson-2
2) C. Israelsson	Turkey Point	Neckarwestheim GKN
3) A. Uruburu	OBRIGHEIM	OBRIGHEIM-2
4) R. Pérez	OBRIGHEIM	OBRIGHEIM-2
5) I. García	Genkai-1	Turkey Point
6) P. Díaz	Gosgen	Beznau
7) L. Cevallos	OBRIGHEIM-2	OBRIGHEIM
8) M. García	OBRIGHEIM-2	OBRIGHEIM
9) Á. López	Neckarwestheim GKN	Genkai-1
10) E. Morgado	Beznau 1 (ITU/Karlsruhe)	Gosgen
11) G. López	Beznau 1 (ITU/Karlsruhe)	Gosgen
12) J. Garrido	Vandellos	Yankee
13) P. Romojaro	Vandellos	Yankee
14) R. Rey	Yankee	Mihama-3
15) A. Jiménez	Yankee	Mihama-3
16) I. Fernández	Mihama-3	Vandellos
17) A. Sabater	Mihama-3	Vandellos
18) A. García	H.B.Robinson-2	Ohi
19) Á. Burgos	H.B.Robinson-2	Ohi

Reactor and Review Assignments



1. Beznau-I (by E. Morgado and G. López)

❑ **Description of the work:**

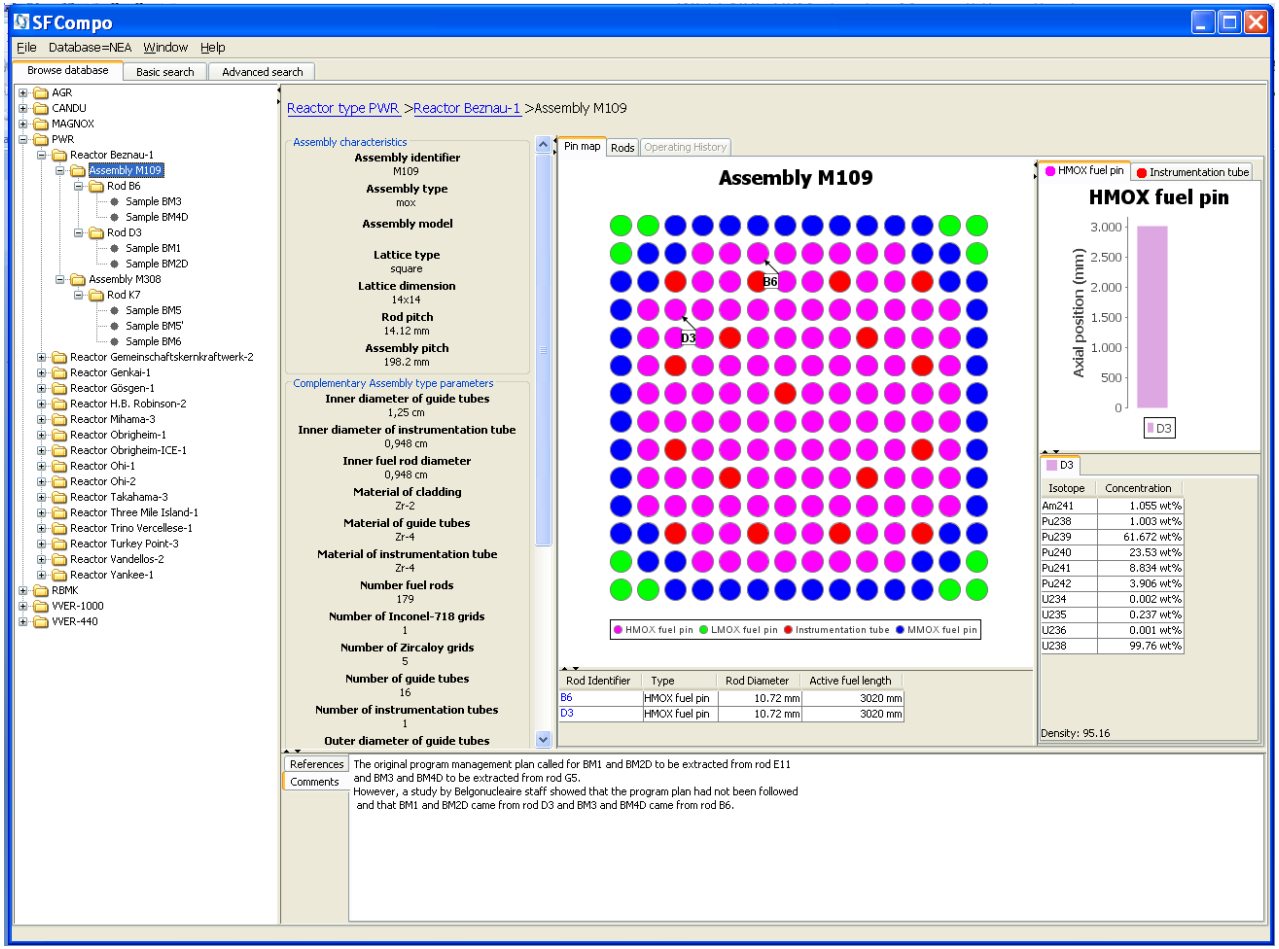
PWR Westinghouse (Switzerland)

➢ Assembly M109 → 4 samples from 2 rods: B6, D3

Due to problems during transportation (cask rotation) samples for analysis were extracted from mistaken rods

➢ Assembly M308 → 2 samples from rod K7

This analysis was introduced due to the unexpected cask rotation problem with M109



1. Beznau-I (by E. Morgado and G. López)

❑**Problems:**

i. Results from one laboratory were rejected due to the overestimation of U content

ii. A cross-check analysis was performed on two samples to provide recommended values for each isotope. Used for its implementation in SFCOMPO

iii. Isotopes with significant decay or buildup during the period from end of fuel operation (EOL) to last measurement were corrected

❑**Problems in the implementation of data in SFCOMPO:**

i. Add “new” units for some of the measurements performed in the laboratories as well as the corrected EOL calculations

ii. It was difficult to address the cask rotation problem in the SFCOMPO application, but this was solved with the “*Comment Tool*” implemented in the latest stage of development

❑ **Main References:**

[1] ARIANE International Programme — Final Report, ORNL/SUB/97-XSV750-1, Oak Ridge National Laboratory, Oak Ridge, Tenn., May 2003

[2] Expert Group on Assay Data for Spent Nuclear Fuel – Evaluation of ARIANE Experiments– Beznau BM1 Sample Measurements, Pedro Ortego, SEA Ingeniería y Análisis de Blindajes S.L.

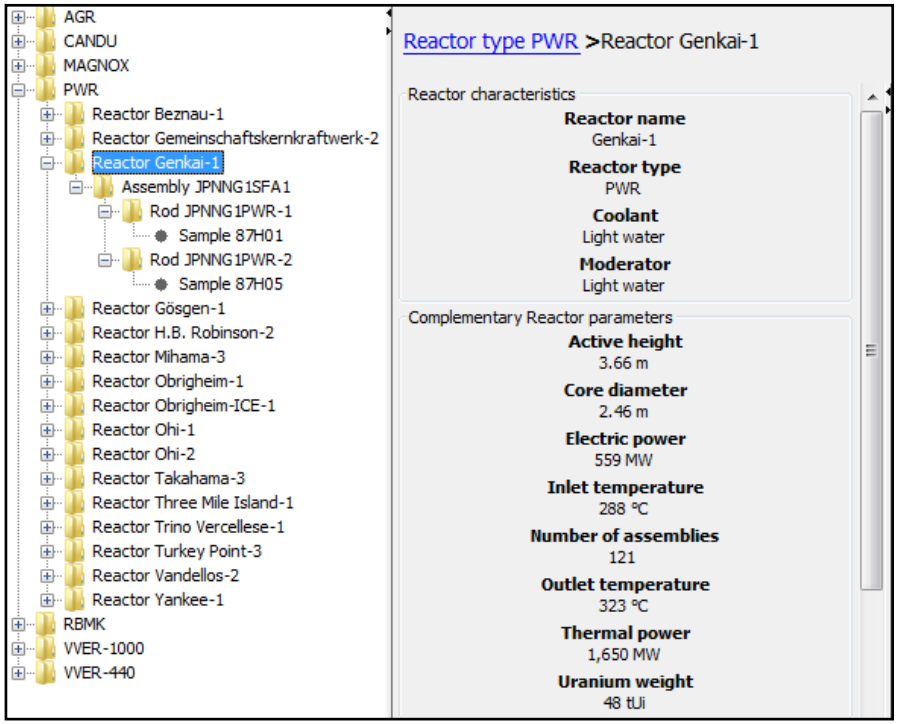
2. Genkai-1 (by I. García)

❑ Description of the work

Two samples were taken from the JPNNG1SFA1 assembly irradiated in the Genkai Unit 1 PWR reactor.

Sample ID	Sample Name
JPNNG1PWR-1	87H01
JPNNG1PWR-2	87H05

The results obtained from the post irradiation examination conducted by JAERI were sorted out in a spreadsheet that was then uploaded to the application

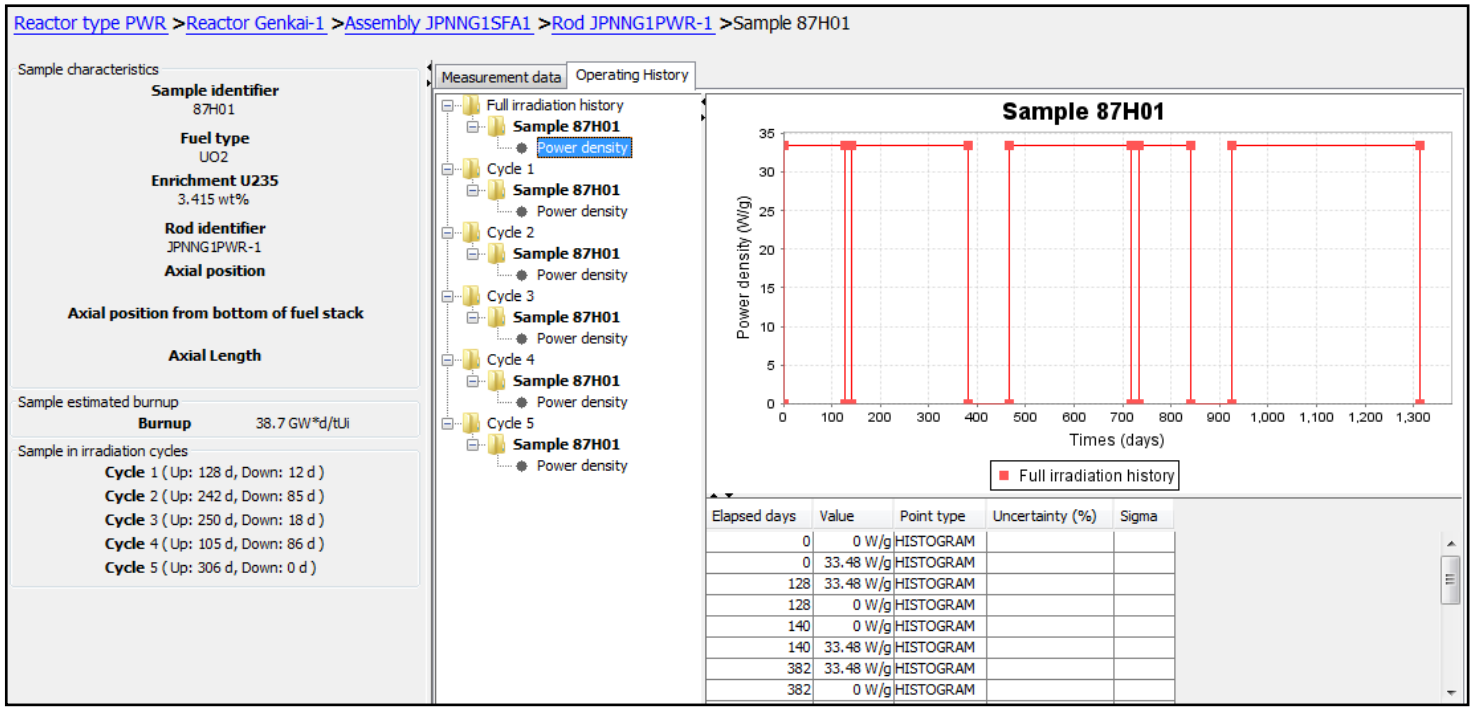


Reactor characteristics (screenshot from SFCOMPO)

2. Genkai-1 (by I. García)

❑ Assumptions

- Dummy reference dates were used, because no records about measurements dates
- Power density through the reactor's operation history was assumed constant.



2. Genkai-1 (by I. García)

❑ Problems

- Reactor's assembly type is **14x14**, old type even in the 1990's.
- The data set of Genkai-1 reactor includes **only two points**, clearly less than other reactors
- The **location of the Genkai-1 sample/assembly** was reported **classified** (neither a pin map nor an axial zoning graph could be generated on the SFCOMPO Java application)

❑ Main References

[1] Y. Nakahara, K. Suyama, and T. Suzaki. "Technical Development on Burn-Up Credit for Spent LWR Fuels." JAERI-Tech 2000-071(2000)

[2] H. Mochizuki, K. Suyama, Y. Nomura, and H. Okuno. "Spent Fuel Composition Database System on WWW - SFCOMPO onWWW Ver.2-." JAERI Data/Code 2001-020 (2001)

3. Gösgen (by P. Díaz)

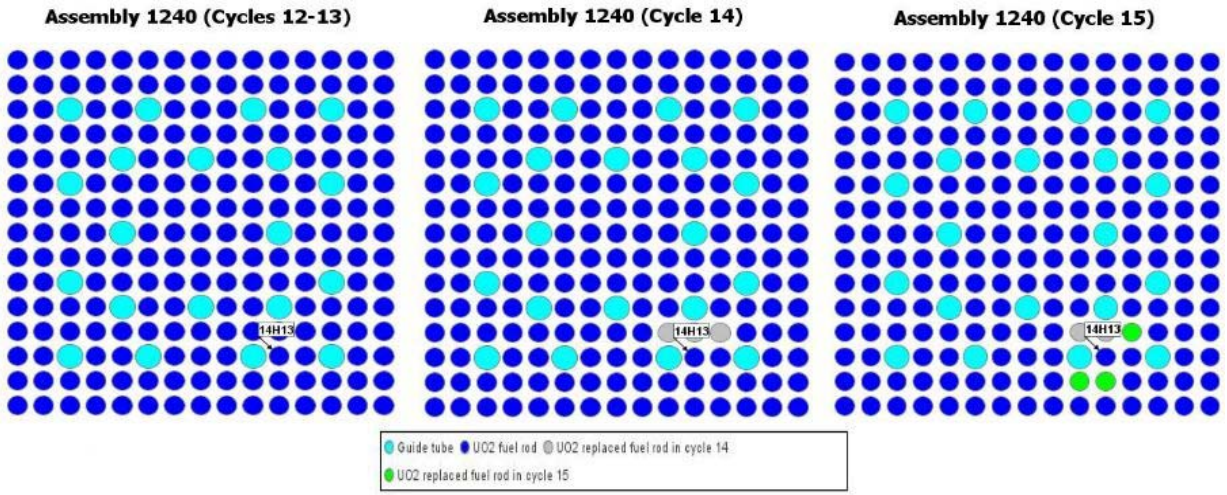
❑ Description of the work

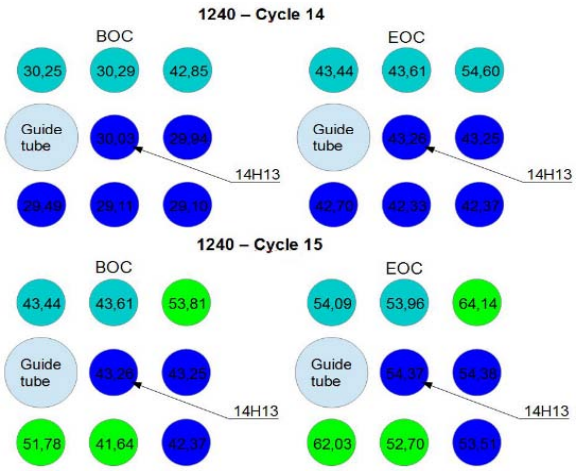
- 3 assemblies containing 4 samples

Assembly	Rod	Sample	Assembly
1240	14H13	GU1 & GU2	12-13-14-15
1601	16B05	GU3(') & GU4	16-17
1701	16B05	GU3(') & GU4	18

- Measurements for GU2 were rejected, so it was not implemented into SFCOMPO.
- The fuel rod 16B05 was irradiated for cycles 16 and 17 in assembly 1601 and then transferred for cycle (18) in assembly 1701.
- Sample GU3 can be considered as two samples, GU3 and GU3'. They have been implemented into SFCOMPO as independent samples.

- Assembly 1240
  - Implementation in function of the irradiation cycles because some fuel rods surrounding the sample rod were changed





Burnup of replaced rods

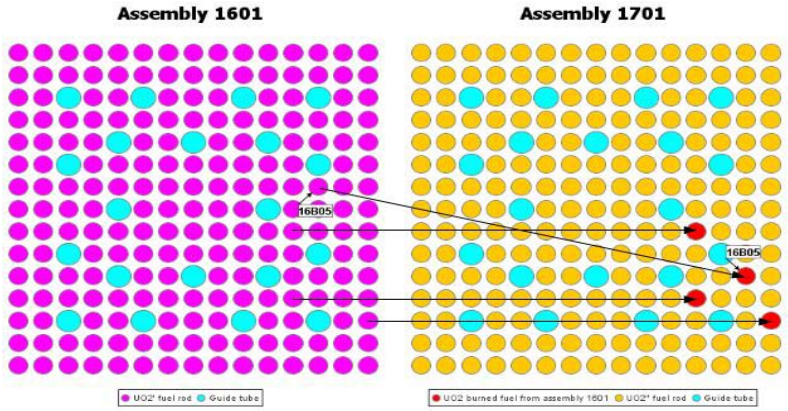
3. Gösgen (by P. Díaz)

❑ Description of the work

- Assemblies 1601 and 1701

  - Fuel assemblies 1601 and 1701 share the same samples (GU3, GU3' and GU4). The samples were irradiated for cycles 16-17 in assembly 1601 and then transferred to assembly 1701

  - The assemblies were implemented in SFCOMPO separately



❑Problems

- SFCOMPO only admits one pin map per assembly

- Difficult to incorporate the replaced rods burnup in assembly 1240

❑ Main References

[1] *ARIANE International Programme — Final Report*, ORNL/SUB/97-XSV750-1, Oak Ridge National Laboratory, Oak Ridge, Tenn., May 2003.

4. H.B.Robinson Unit-2 (by A. Burgos and A. García)

❑ Description of the work

Study of six different samples:

- ❑ ROD N9: 4 samples
- ❑ ROD P8: 2 samples

Data:

- ❑ Measurements → Divided in { Concentrations; Ratios; Burn-up }
- ❑ Operation cycles → Temp & Power of each cycle
- ❑ Core design and shape and size of the rods

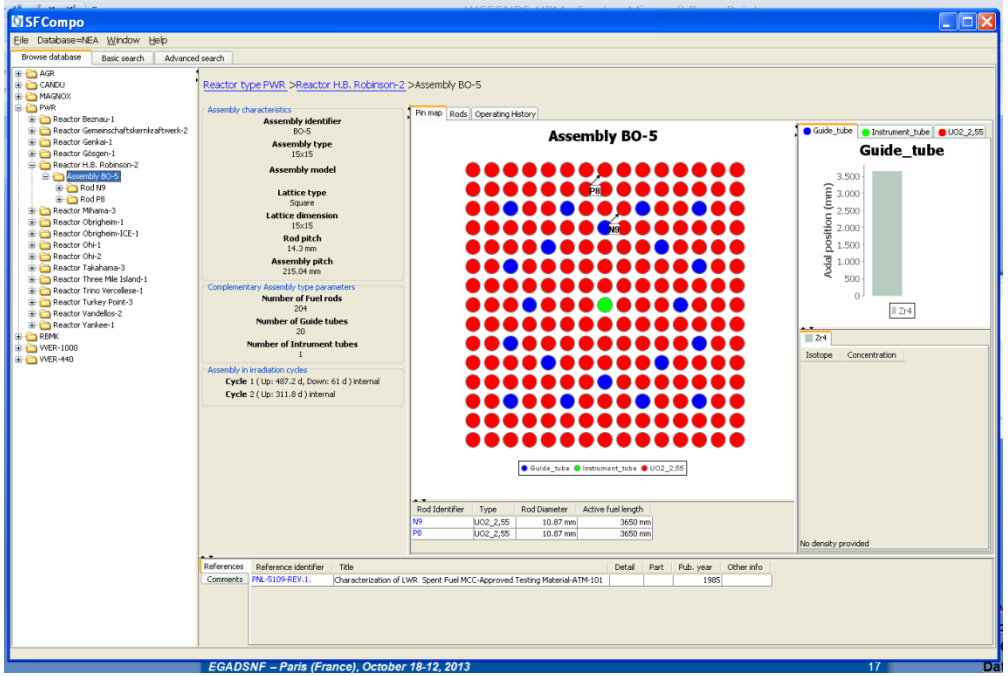


Fig. Assembly information

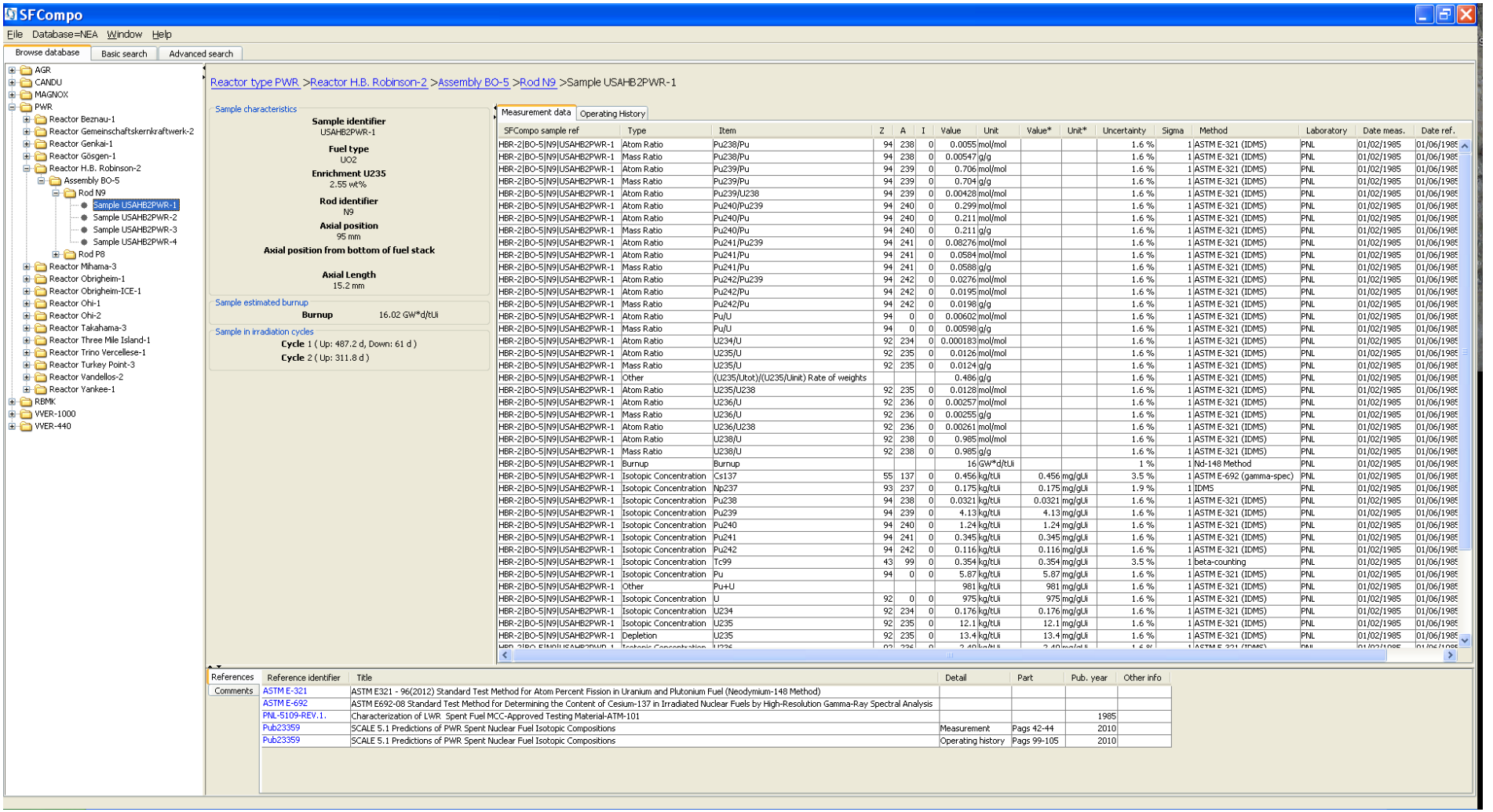
Problems:

- ❑ Some difficulties with the units and the nomenclature of special ratios
- ❑ Operation information was collected from different reports

References

[1] PNL-5109-REV.1. : Charact. LWR Spent Fuel MCC-Approved Testing Material-ATM-101
[2] SFCOMPO Database: Post Irradiation Examination for the Spent Fuel Samples
[3] ASTM E-692: ASTM E692-08 Standard Test Method for Determining the Content of Csi37 in …
[4] LA-9647-PR: W.B.Wilson et.al. Spent LWR Fuel Inventory Benchmarks. pp.75-88, 1982.
[5] SFCOMPO97 : The isotopic compositions database …
[6] ASTM E-321: ASTM E321 - 96(2012) Standard Test Method …
[7] Pub23359: SCALE 5.1 Predictions of PWR Spent Nuclear …

4. H.B.Robinson Unit-2 (by A. Burgos and A. García)



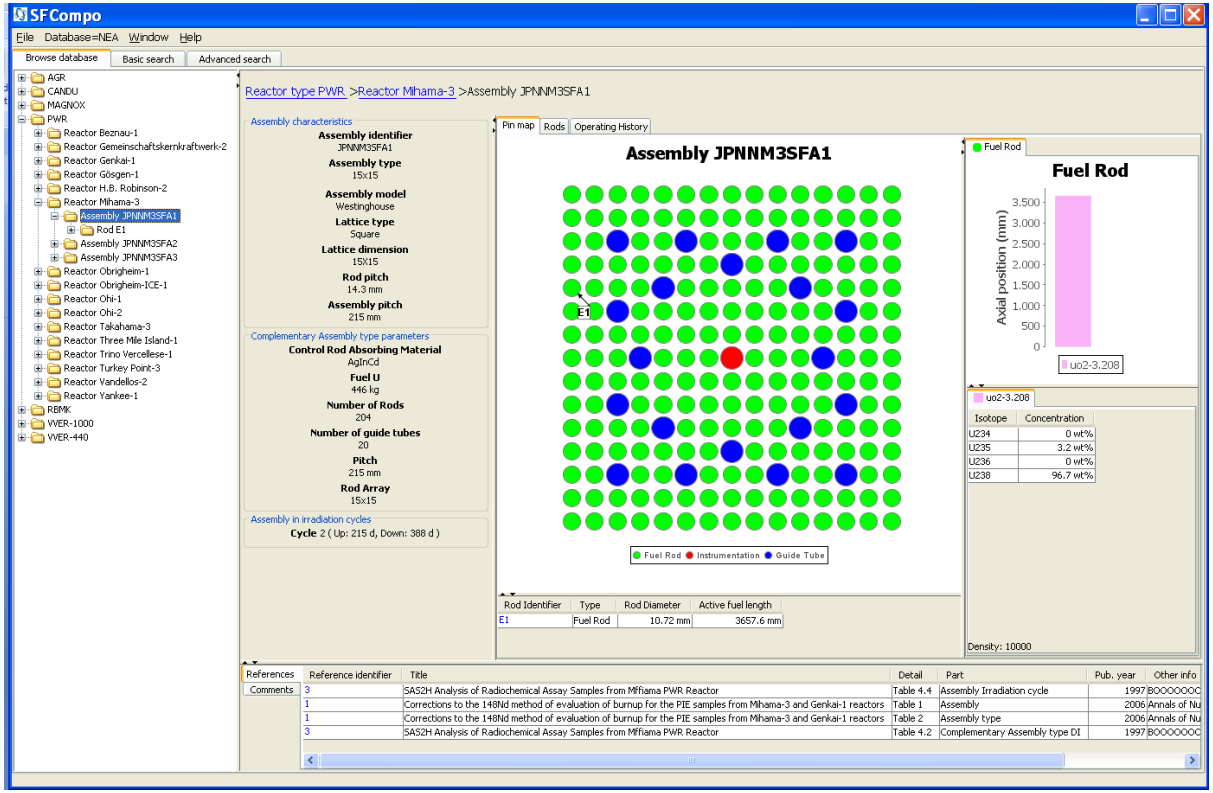
SFCompo sample ref	Type	Item	Z	A	I	Value	Unit	Value*	Unit*	Uncertainty	Sigma	Method	Laboratory	Date meas.	Date ref.
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	Pu238/Pu	94	238	0	0.0055	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Mass Ratio	Pu238/Pu	94	238	0	0.00547	g/g			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	Pu239/Pu	94	239	0	0.706	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Mass Ratio	Pu239/Pu	94	239	0	0.704	g/g			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	Pu239/U238	94	239	0	0.00428	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	Pu240/Pu239	94	240	0	0.299	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	Pu240/Pu	94	240	0	0.211	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Mass Ratio	Pu240/Pu	94	240	0	0.211	g/g			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	Pu241/Pu239	94	241	0	0.08276	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	Pu241/Pu	94	241	0	0.0584	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Mass Ratio	Pu241/Pu	94	241	0	0.0588	g/g			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	Pu242/Pu239	94	242	0	0.0276	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	Pu242/Pu	94	242	0	0.0195	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Mass Ratio	Pu242/Pu	94	242	0	0.0198	g/g			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	Pu/U	94	0	0	0.00602	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Mass Ratio	Pu/U	94	0	0	0.00598	g/g			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	U234/U	92	234	0	0.000183	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	U235/U	92	235	0	0.0126	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Mass Ratio	U235/U	92	235	0	0.0124	g/g			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Other	(U235/Utot)/(U235/Uinit) Rate of weights				0.486	g/g			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	U235/U238	92	235	0	0.0128	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	U236/U	92	236	0	0.00257	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Mass Ratio	U236/U	92	236	0	0.00255	g/g			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	U236/U238	92	236	0	0.00261	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Atom Ratio	U238/U	92	238	0	0.985	mol/mol			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Mass Ratio	U238/U	92	238	0	0.985	g/g			1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Burnup	Burnup				16	GW*d/tUi			1 %	1	Nd-148 Method	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Isotopic Concentration	Cs137	55	137	0	0.456	kg/tUi	0.456	mg/gUi	3.5 %	1	ASTM E-692 (gamma-spec)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Isotopic Concentration	Np237	93	237	0	0.175	kg/tUi	0.175	mg/gUi	1.9 %	1	IDMS	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Isotopic Concentration	Pu238	94	238	0	0.0321	kg/tUi	0.0321	mg/gUi	1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Isotopic Concentration	Pu239	94	239	0	4.13	kg/tUi	4.13	mg/gUi	1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Isotopic Concentration	Pu240	94	240	0	1.24	kg/tUi	1.24	mg/gUi	1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Isotopic Concentration	Pu241	94	241	0	0.345	kg/tUi	0.345	mg/gUi	1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Isotopic Concentration	Pu242	94	242	0	0.116	kg/tUi	0.116	mg/gUi	1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Isotopic Concentration	Tc99	43	99	0	0.354	kg/tUi	0.354	mg/gUi	3.5 %	1	beta-counting	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Isotopic Concentration	Pu	94	0	0	5.87	kg/tUi	5.87	mg/gUi	1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Other	Pu+U				981	kg/tUi	981	mg/gUi	1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Isotopic Concentration	U	92	0	0	975	kg/tUi	975	mg/gUi	1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Isotopic Concentration	U234	92	234	0	0.176	kg/tUi	0.176	mg/gUi	1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Isotopic Concentration	U235	92	235	0	12.1	kg/tUi	12.1	mg/gUi	1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985
HBR-2|BO-5|N9|USAHB2PWR-1	Depletion	U235	92	235	0	13.4	kg/tUi	13.4	mg/gUi	1.6 %	1	ASTM E-321 (IDMS)	PNL	01/02/1985	01/06/1985

Measurement information **SFCOMPO Database**

5. Mihama-3 (by A. Sabater and I. Fernández)

❑ Description of the work

An important part of the required information was found in the former SFCOMPO data base, but also important information about the cycles (burnup, power) and isotopic concentration was found in "*SAS2H document*".



❑Problem

There is not information about axial position of the sample in the rod

❑ Main References

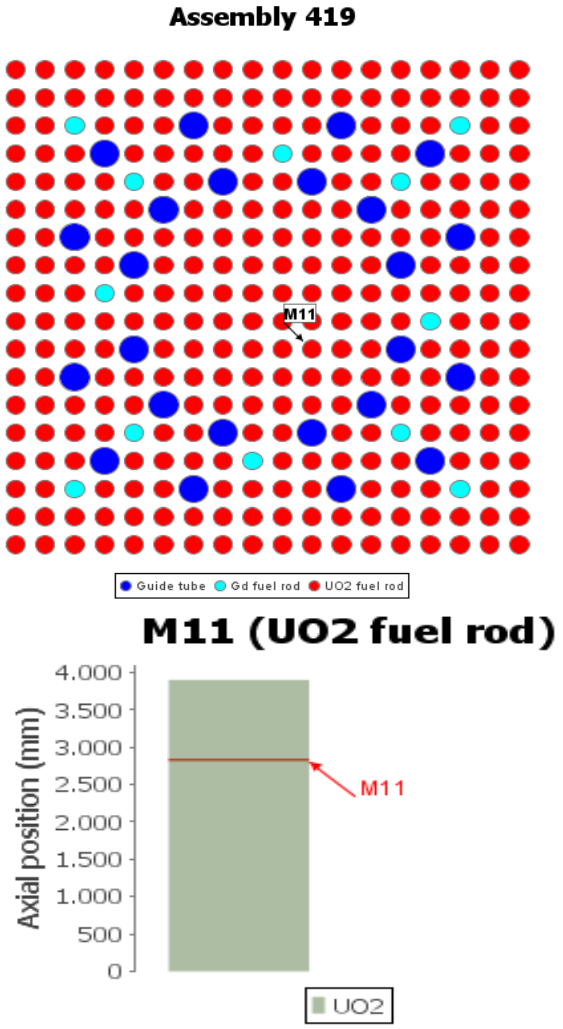
[1] Post Irradiation Examination For the Spent Fuel Samples. Old SFCOMPO
[2] Corrections to the Nd method of evaluation of burnup for the PIE samples from Mihama-3 and Genkai-1 reactors.
[3] Kenya Suyama, Hiroki Mochizuki. Annals of Nuclear Energy 33 (2006) 335–342
[4] SAS2H Analysis of Radioch. Assay Samples from Mihama PWR Reactor. BOOOOOOOO-01717-0200-00144 REV 00
[5] Data Book of the Isotopic Composition of Spent Fuel in Light Water Reactors

6. Neckarwesthein-GKN II (by A. López)

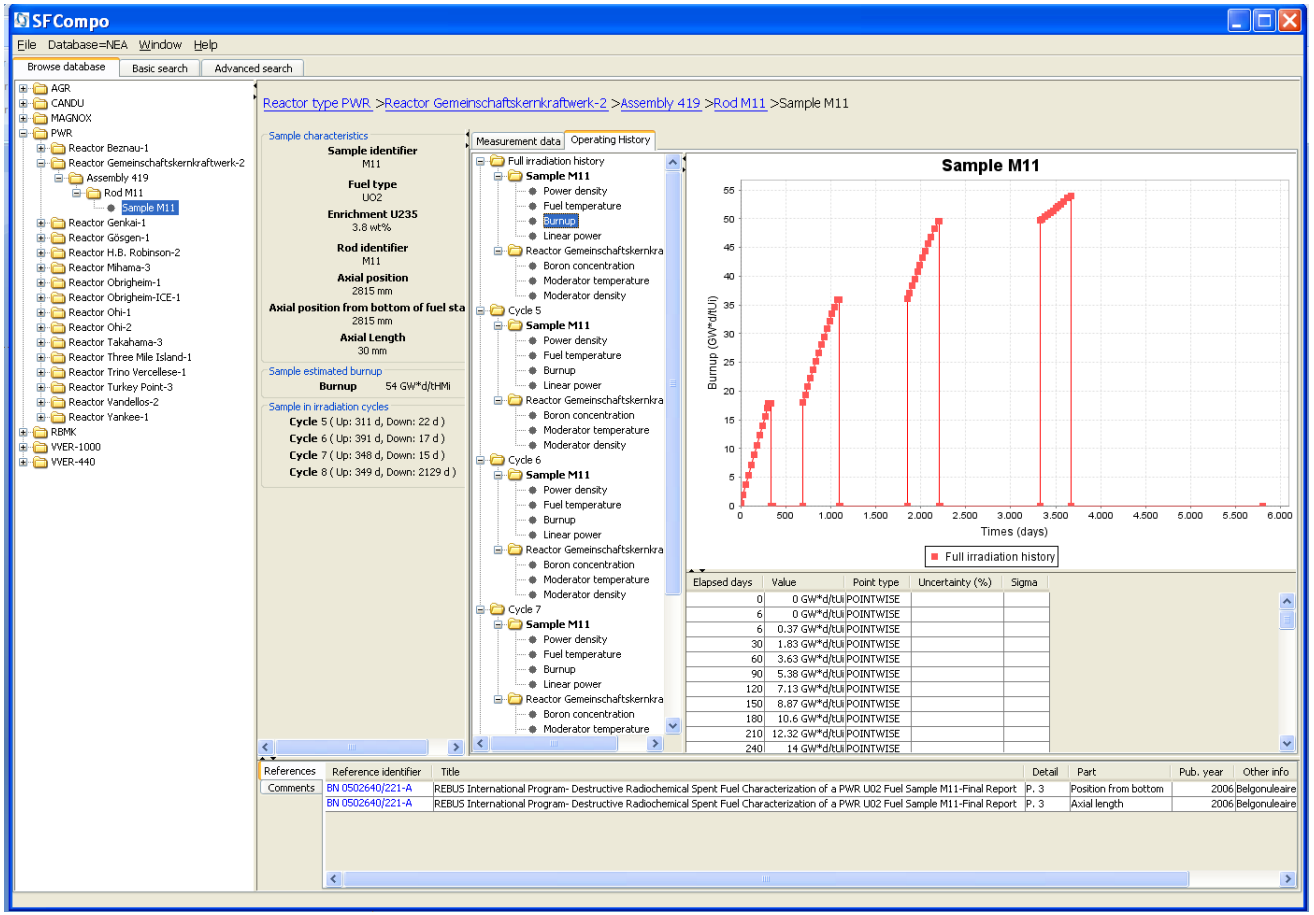
❑ Description of the work

- Pressurized Water Reactor – 18x18
- Sample M11 from assembly 419 (UO_2)
- Enrichment 3.8 wt %
- The analyses were performed at SCK-CEN, and depending on the measured isotope, the laboratory used:
  - α-spectrometry
  - γ-spectrometry
  - Thermal Ionisation mass spectrometry (TIMS)
  - Inductively coupled plasma mass spectrometry (ICP-MS)

- M11, irradiation: 5 cycles (1445.4 days)
- Only separation date for Am-241, Am-242m and Am-243



6. Neckarwesthein-GKN II (by A. López)



❑ Main References

[1] Belgonucleaire S. A., SCK-CEN, *REBUS Int. Pro.: γ Spectr. PIE on Irrad. GKN II fuel rods (BN Reference: 0403182/221*), December 2004

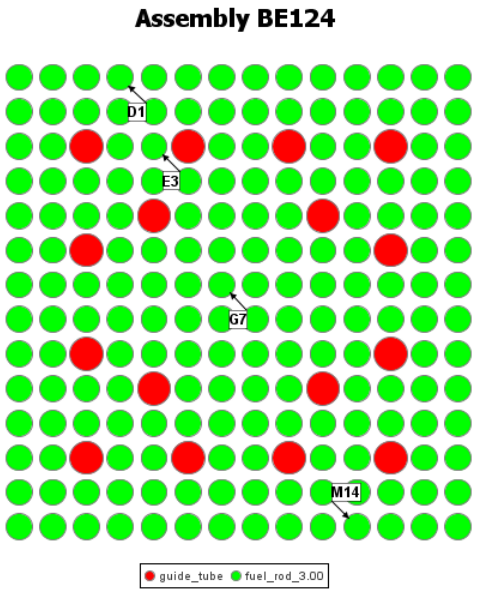
[2] Belgonucleaire S. A., SCK-CEN, *REBUS Int. Pro.:* Fuel Irradiation History Report *(BN Reference: 0501278/221-Rev.B),* June 2005

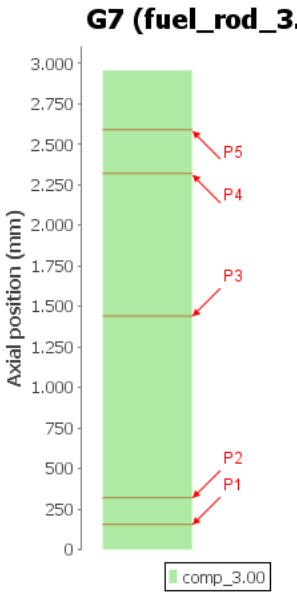
[3] Belgonucleaire S. A., SCK-CEN, *REBUS Int.Pro.: Destr. Radioc. Spent Fuel Charact. of a PWR U02 Fuel Sample (BN Reference:* 0502640/221-*Rev.A*), May 2006

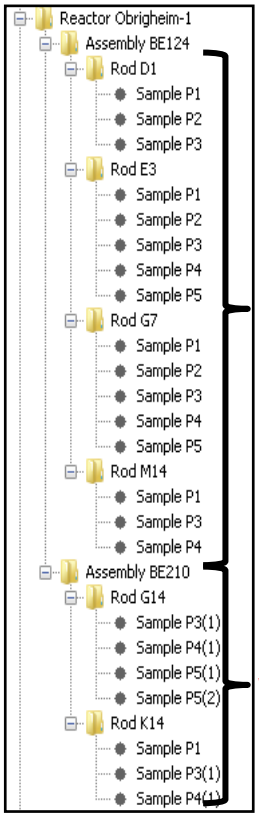
7. Obrigheim-1 (by M. García and L. Cevallos)

❑ Description of the work

- **20 samples** at different heights were taken from 6 rods and 2 fuel assemblies of different enrichment, and explored via gamma spectrometry and radiochemical analyses amongst other techniques







- Information was collected from different sources and added to the one already available in the previous SFCOMPO version. Most of the data were retrieved from document EUR 6589en, complemented with ORNL/TM-2010/44 when something was missing

7. Obrigheim-1 (by M. García and L. Cevallos)

❑ **Difficulties were found regarding the following aspects:**

1) Measurements of (Pu238 + Am241)/(Pu239 + Pu240) and Pu238/(Pu239 + Pu240) in the same sample are supposed to be taken in that order, before and after the chemical separation of Am241. That information is recorded in P. 153 Table VII in document EUR6589en.

   - Some of the measurements **after** separation have an associated date previous to the data **before** separation. Example: OBR1|BE124|D1|P2.

2) Some information present in the bibliography was worthy of inclusion but the present format of the SFCOMPO java application is not able to deal with it. It is suggested to enlarge the capability of handling the data in order to offer this and other additional data:

   - Moderator Temperature and Density, as shown in P. 94, Table 56 in ORNL/TM-2010/44
   - Comparison between the relative results obtained by different experimental techiques at different laboratories, as shown in P. 159-168 in EUR6589en

3) It should be noted that document EUR6589en has some of its pages unordered. Page 166 should follow page 159.

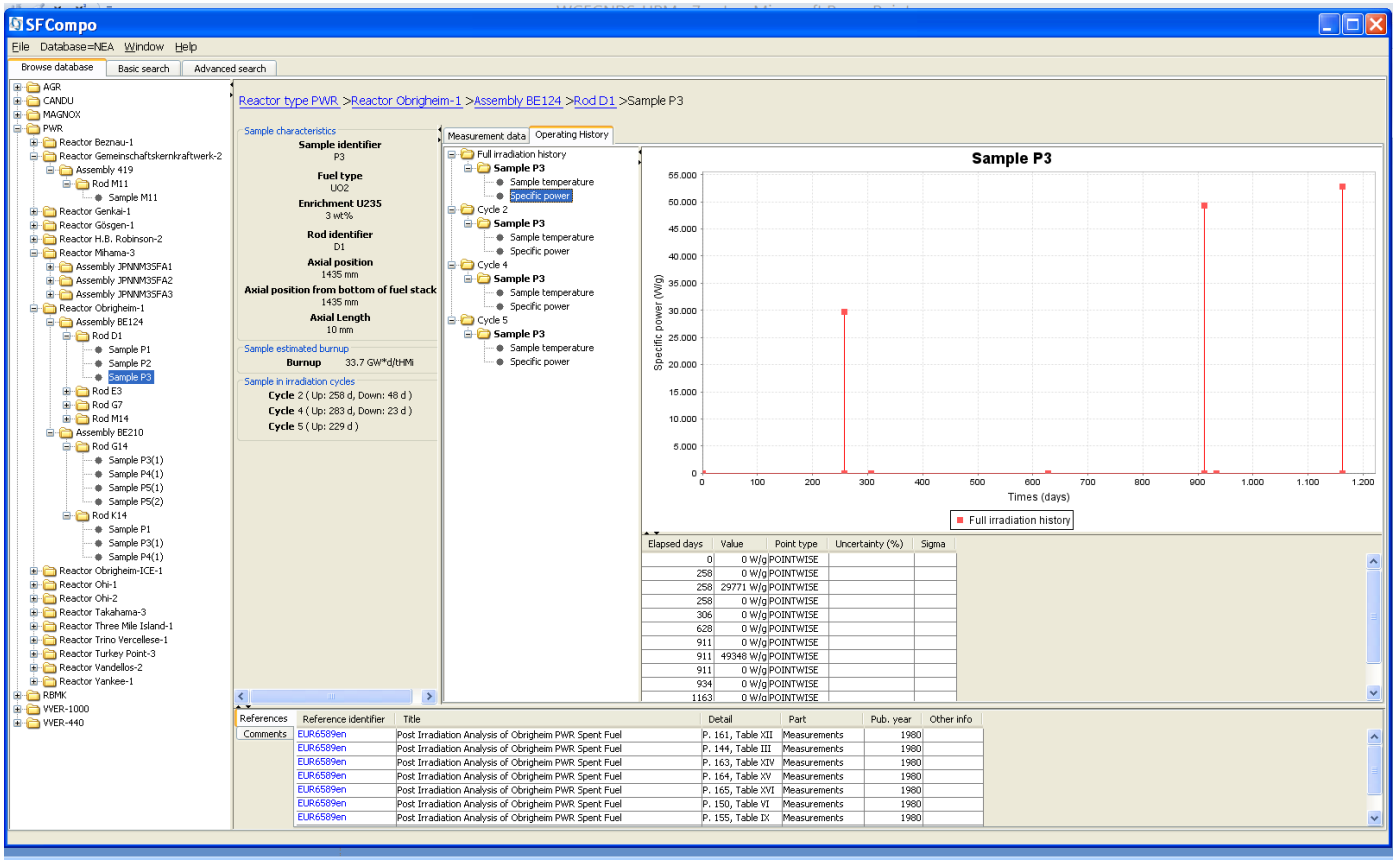
7. Obrigheim-1
(by M. García and L. Cevallos)

❑ Main references

[1] "Post irradiation inalysis of the Obrigheim PWR spent fuel". European Appl. Res. Rept. – Nucl. Sci. Technol. Vol. 2 No. 1 (1980) , pp. 129-177. Referred as: EUR6589en

[2] "SCALE 5.1 Predictions of PWR Spent. Nuclear Fuel Isotopic Compositions". March 2010. Refererred as: ORNL/TM-2010/44

[3] "BENCHMARK. Reference Data on Post Irradiation Analysis of Light Water Reactor Fuel Samples". Referred as: EUR7879en



8. Obrigheim-ICE (by A. Uruburu and R. Pérez)

❑ Description of the work

- PWR, 345 Mwe, 1050 MWth, 121 fuel assemblies
- *Fuel assembly*: square, 14 x 14, 180 fuel rods, enrichment 3.13% U-235
- Fuel irradiated from **9/1972** to **6/1975.** Operating cycles 3,4 and 6
- ICE measurements **1977-1978**
- **Isotopic Correlation Experiment -ICE-** measurements performed independently at:
  - o European Institute for Transuranium Elements (ITU)
  - o Institute for Radiochemistry at Karlsruhe (IRCh)
  - o Karlsruhe Reprocessing Plant (WAK)
  - o International Atomic Energy Agency (IAEA)

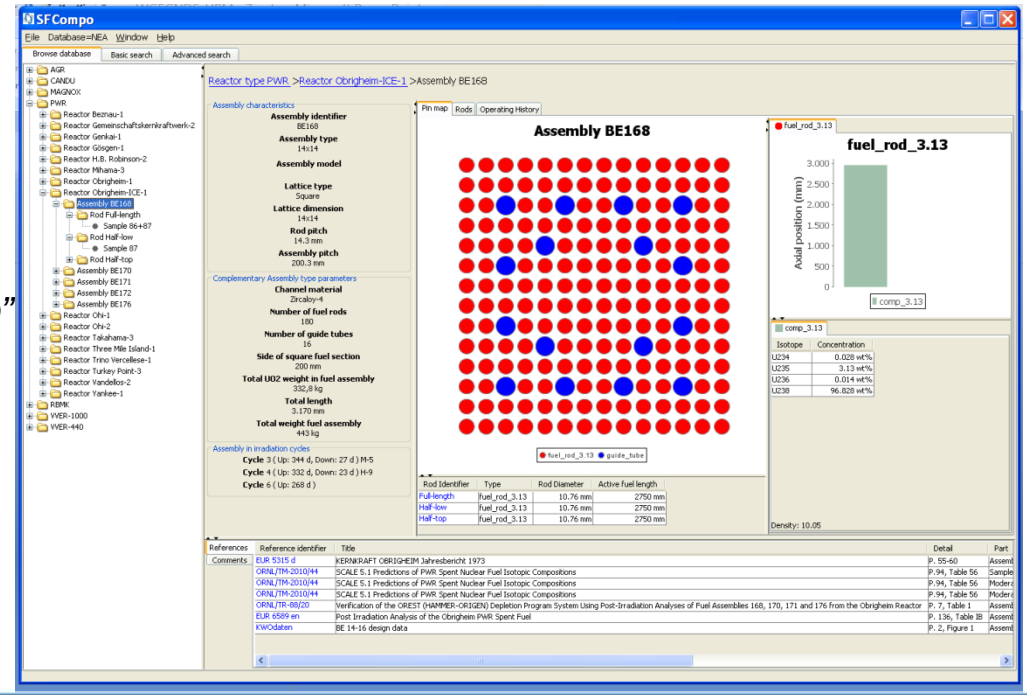
But,

- Original measurements not available: "lack of info"

- Data obtained from several reports referring ICE

- Many data graphically determined from figures

- Slightly different values between reports



8. Obrigheim-ICE (by A. Uruburu and R. Pérez)

❑ Description of the work

Samples (some differences from other reactors)

- 5 fuel assemblies analysed:
- Each assembly divided lenghtwise and analysed in two batches

SFCOMPO structure: **ASSEMBLY/ROD/SAMPLE**

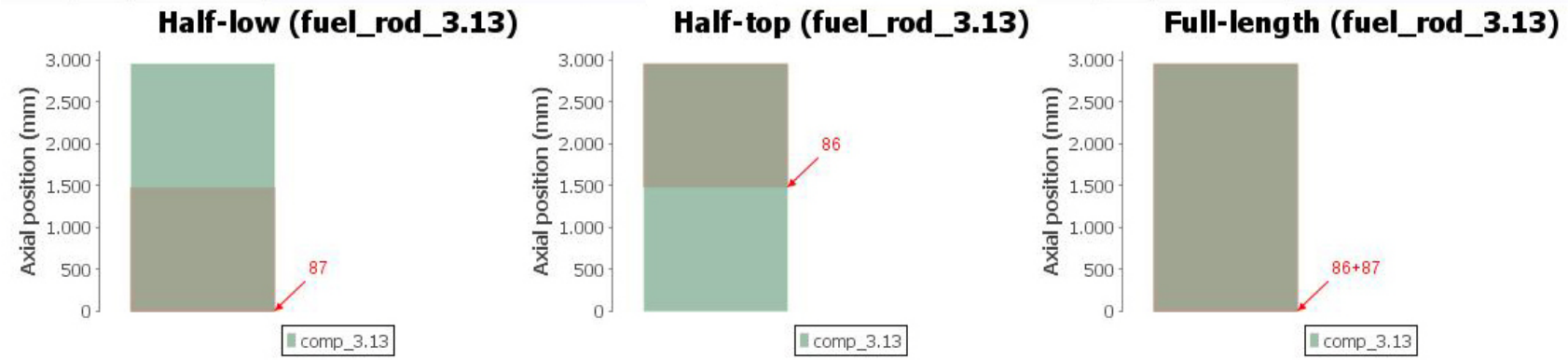
Samples structure: **BE168 / Half-top / 86**

- there is no rod identifier for samples : ”virtual” rod defined: “Half-top”…-

“Assembly average data included “: → **BE168 / Full-length / 86+87**

Table 01: Connection between fuel assemblies and batches

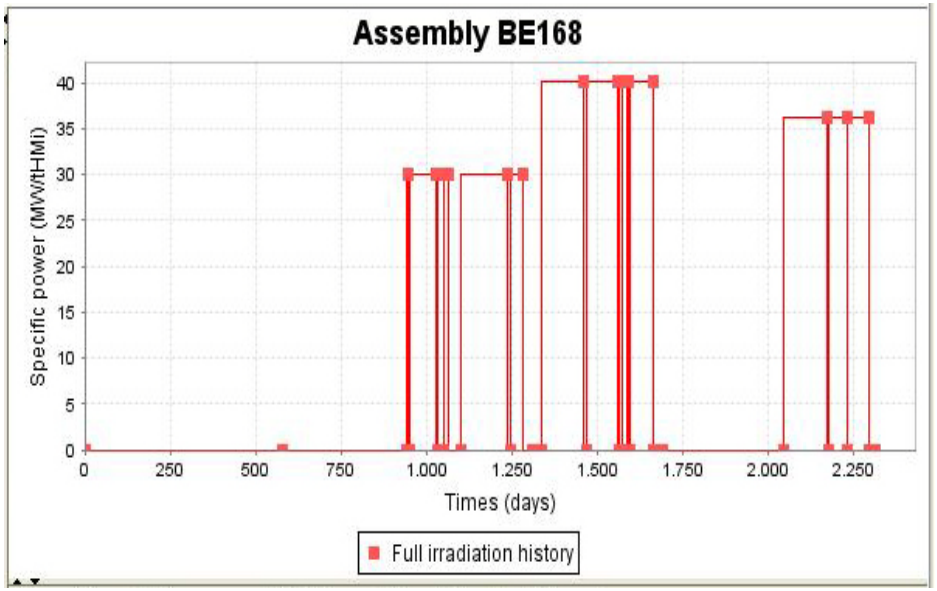
Assembly	Batch	Axial position
BE168	86	Half-top
	87	Half-low
BE170	94	Half-top
	95	Half-low
BE171	88	Half-top
	89	Half-low
BE172	92	Half-top
	93	Half-low
BE176	90	Half-low
	91	Half-top



8. Obrigheim-ICE (by A. Uruburu and R. Pérez)

❑ Description of the work

- Power history: Full/Zero Load operation
- Final Burnup: 26.9 -30.1 GWd/tHM
- Sample temperature: average value
- Moderator temperature and density: average value for all fuel assemblies and cycles
- Boron concentration: average value: 450 ppm



❑ Main References

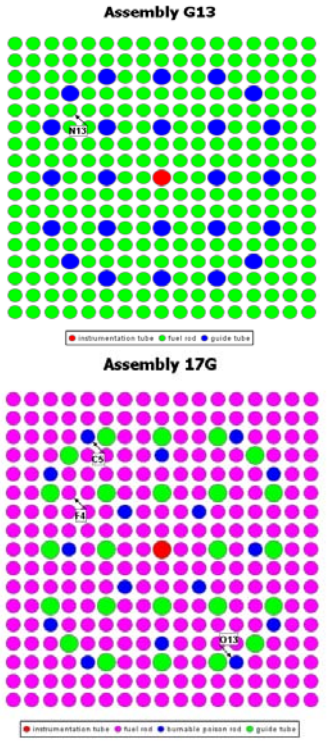
[1] *U. Hesse, Gesellschaft für Reaktorsicherheit*, Verification of the **OREST** (HAMMER-ORIGEN) Depletion Program System Using Post-Irradiation Analyses of Fuel Assemblies 168, 170, 171 and 176 from the Obrigheim Reactor, (translated from the German), **ORNL/TR-88/20, 1988**.

[2] *G. Radulescu, I.C. Gauld, G. Ilas,* **SCALE 5.1** Predictions of PWR Spent Nuclear Fuel Isotopic Compositions, **ORNL/TM-2010/44, 2010.**

9. Ohi-1 and Ohi-2 (by R. Ruiz)

❑ Description of the work

PWR Reactor Name	Ohi-1	Ohi-2				
Assembly Name	G13	I7G				
Fuel Assembly Rod Array	17×17	17×17				
Irradiation Period	Dec. 1982 to Dec. 1987	Jul. 1984 to Feb.1987				
Nº of Irradiation Cycle	4	2				
Sample Name	91E07	89G01	89G03	89G05	89G08	89G10
Fuel Pin Position in the Assemblies	N13	C5	C5	O13	F4	F4
Fuel Type of Sample	UO_2	UO_2-Gd_2O_3	UO_2-Gd_2O_3	UO_2-Gd_2O_3	UO_2	UO_2
^{235}U enrichment [wt%]	3.2	1.7	1.7	1.7	3.2	3.2
Burnup [GWd/t]	52.434	21.465	28.717	25.137	30.172	38.496

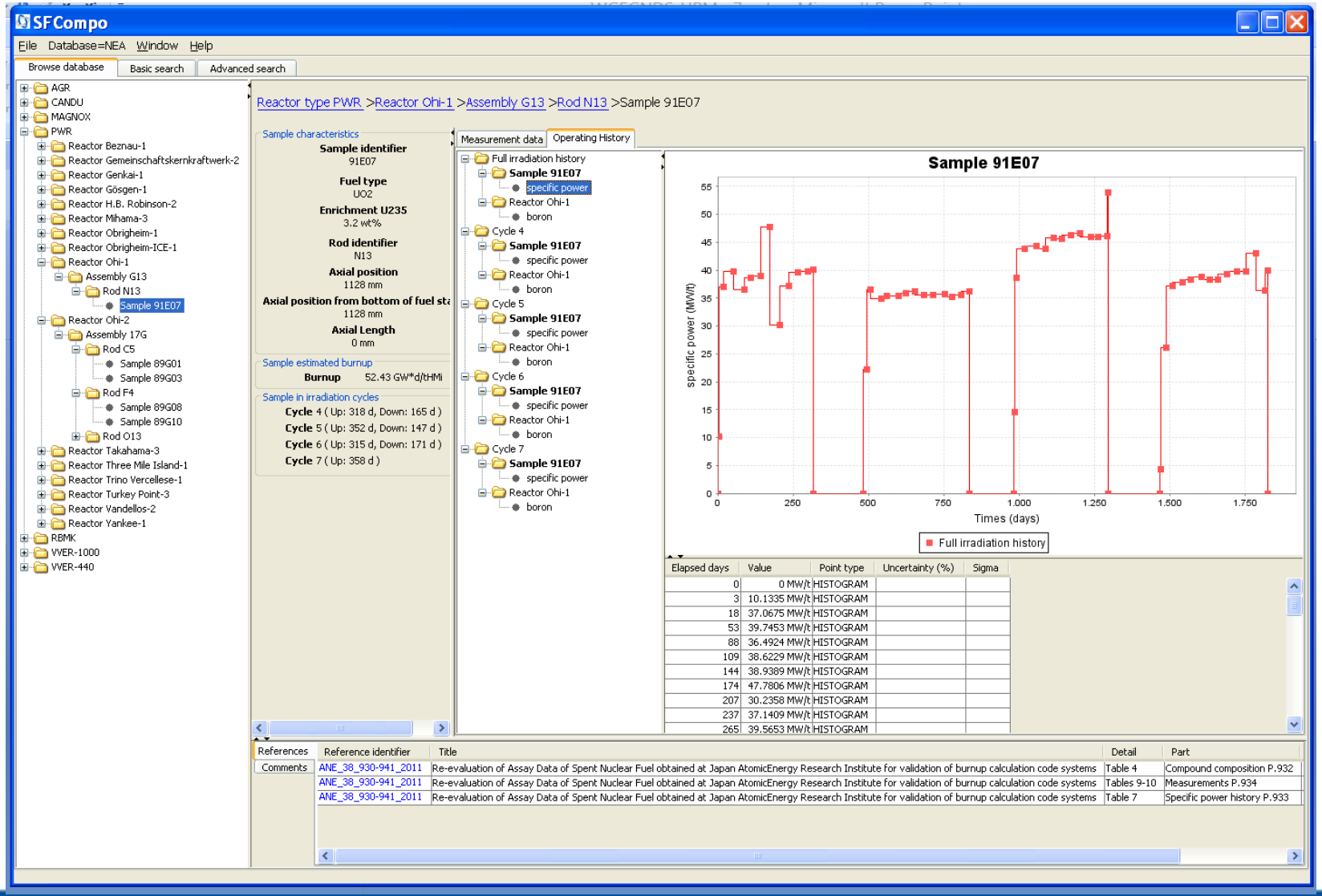


❑ Main References

[1] Suyama K., Murazaki M., Ohkubo K., Nakahara Y., Uchiyama G. T. “Re-evaluation of Assay Data of Spent Nuclear Fuel obtained at Japan Atomic Energy Research Institute for validation of burnup calculation code systems”. Annals of Nuclear Energy, 38, pp.930-941. February 2011

[2] Adachi T., Nakahara Y., Kohno N., Gunji K., Suzuki T., Sonobe T., Onuki M., Kato K., Tachikawa E., Inoue S., Takayasu M., Yoshikuni M., Kobayashi S., Teruya Z., Kawamoto T., Kawamura M. “Comparison of Calculated Values with Measured Values on the Amount of TRU and FP Nuclides Accumulated in Gadolinium Bearing PWR Spent Fuels”. Journal of Nuclear Science and Technology, 31, pp.1119–1129. October 1994

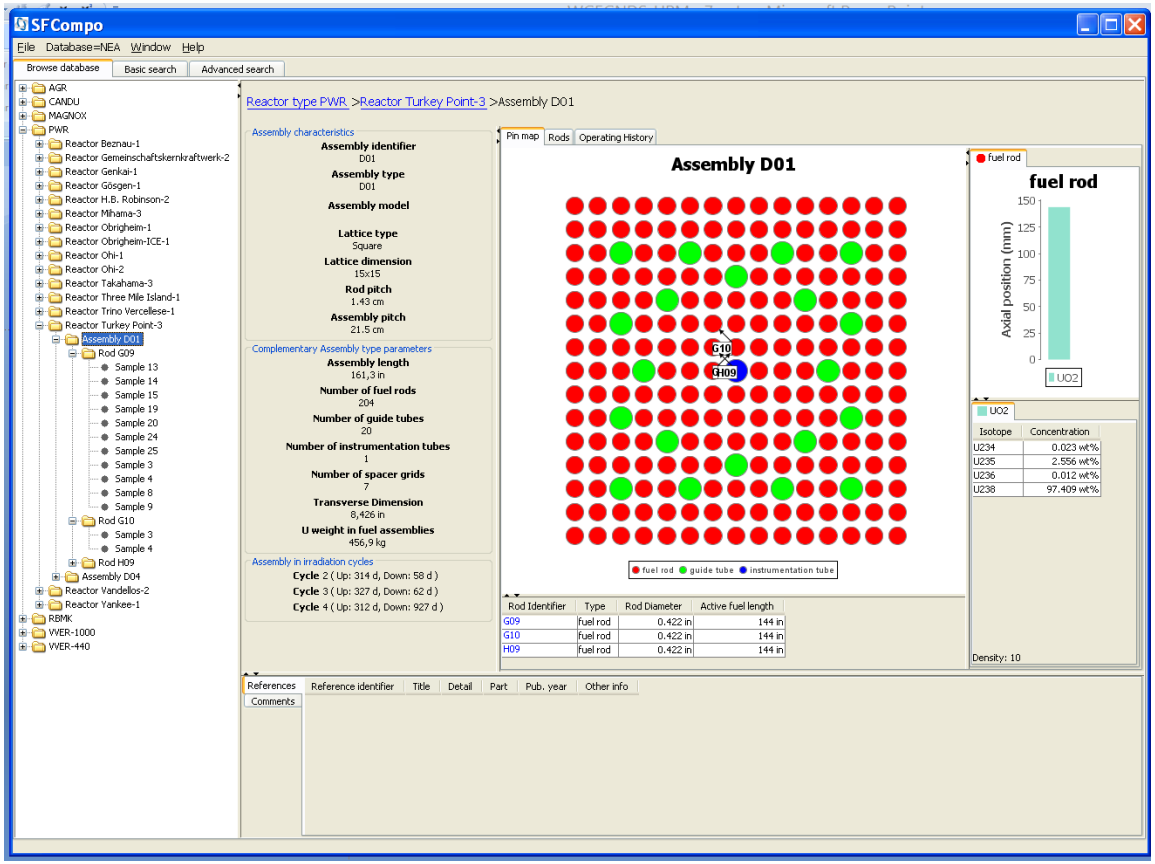
9. Ohi-1 and Ohi-2 (by R. Ruiz)



10. Turkey Point (by C. Israelsson)

❑ Description of the work

From the *"Destructive Examination of 3-cycle LWR fuel rods from Turkey Point Unit 3 for the CLIMAX-Spent Fuel Test, HEDL-TME 80-89"* conducted in the early 1980's : 8 samples for hydrogen analysis, **5 samples for fuel burnup** and 12 samples for metallographic examination

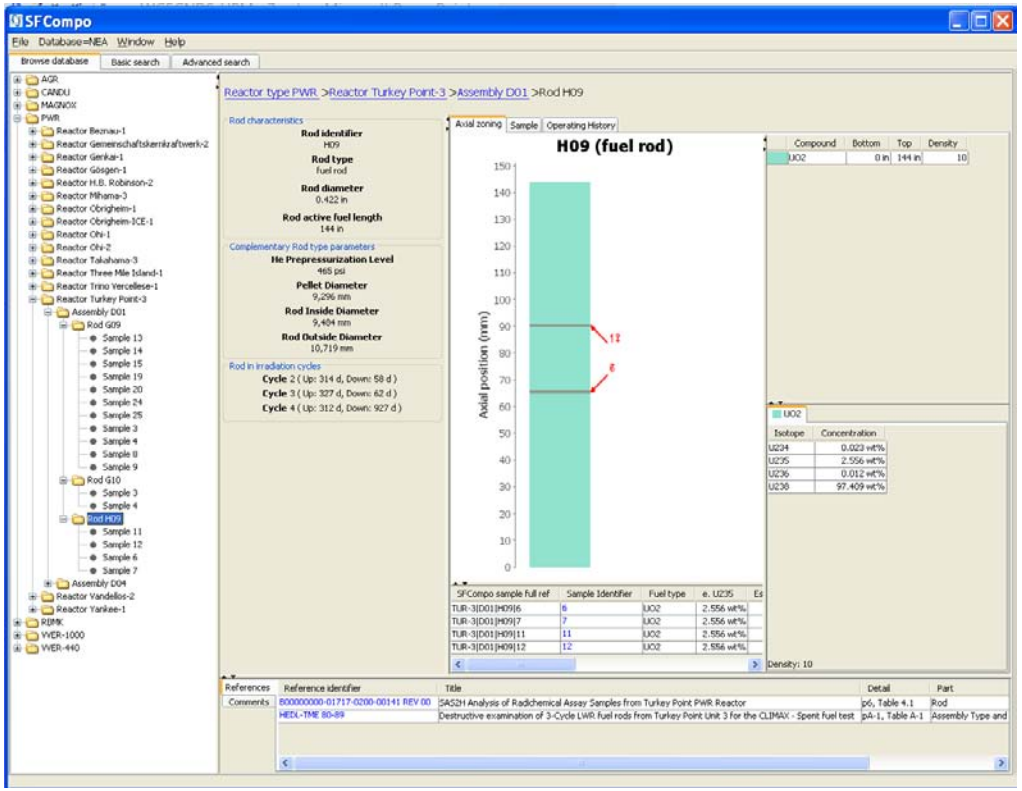


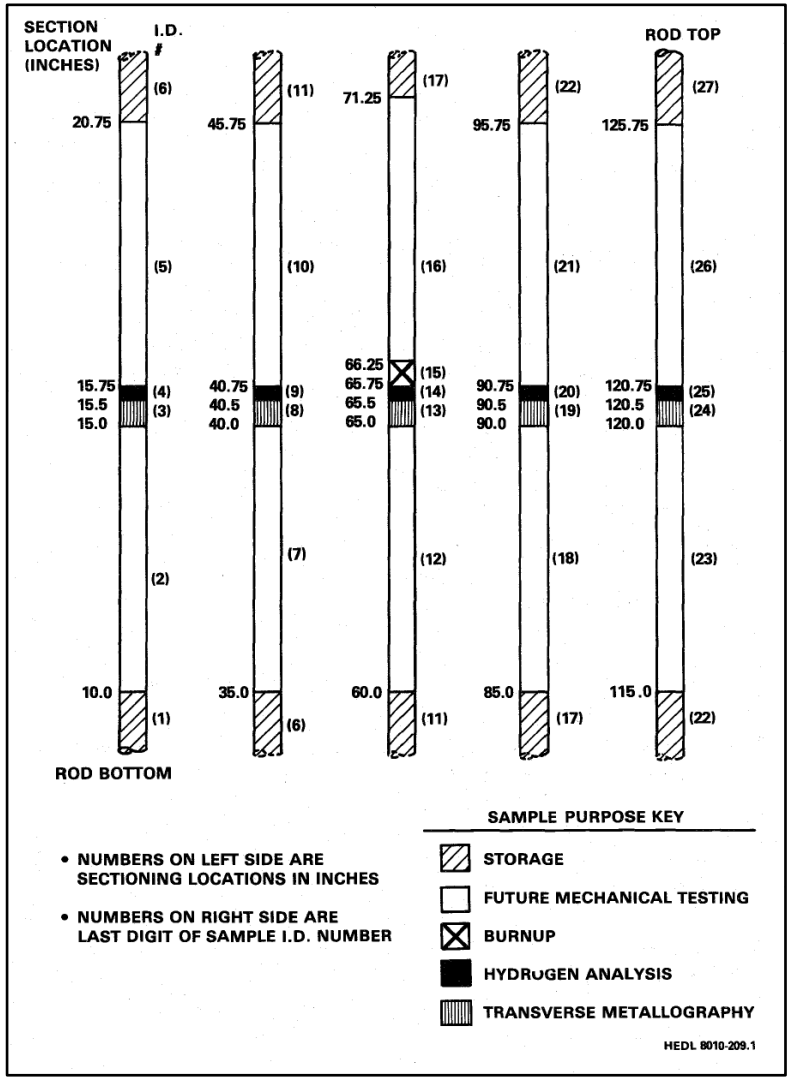
❑This figure shows the transversal section of one of the two (D01 and D04) Turkey Point's assemblies and the place of examined fuel rods, as seen in the SFCOMPO Database.

10. Turkey Point (by C. Israelsson)

- Figure on the right illustrates where the samples were taken.

- Figure below shows how Fuel Rod H09 is showed in SFCOMPO database.





10. Turkey Point (by C. Israelsson)

❑ Issues

- Some data, such as isotopic concentrations, are not consistent: "different results in the references"
- No information about "the localization of assemblies in each irradiation period"
- Some information (fission gas analysis, void volume determination) is not represented in the database since it is not related to any definite sample

❑ Main References

[1] S. D. Atkin Destructive examination of 3-Cycle LWR fuel rods from Turkey Point Unit 3 for the CLIMAX - Spent fuel test Hanford Engineering Development Laboratory

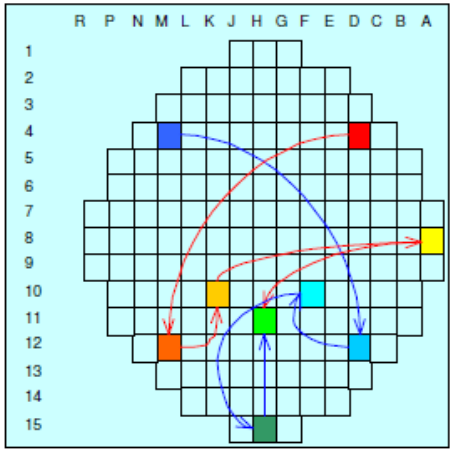
[2] M. Nichol, D. Henderson et al. SAS2H Analysis of Radichemical Assay Samples from Turkey Point PWR Reactor CRWMS/M&O

[3] G. Radulescu et al. SCALE 5.1 Predictions of PWR Spent Nuclear Fuel Isotopic Compositions Oak Ridge National Laboratory

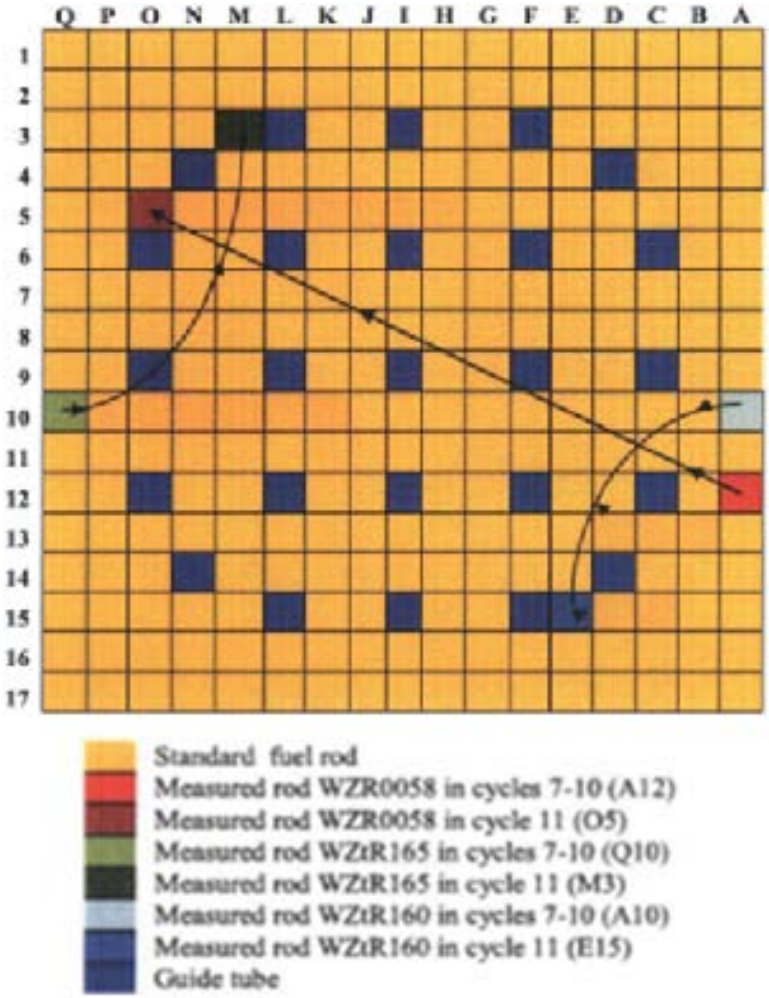
11. Vandellós-II (by J. Garrido and P. Romojaro)

❑ Samples description: Vandellos II

- Many pellets were moved inside the reactor with the intention of performing a high burnup isotope inventory evaluation
- Nine samples were extracted from some rods at different fuel heights by Studsvik Laboratory in Sweden



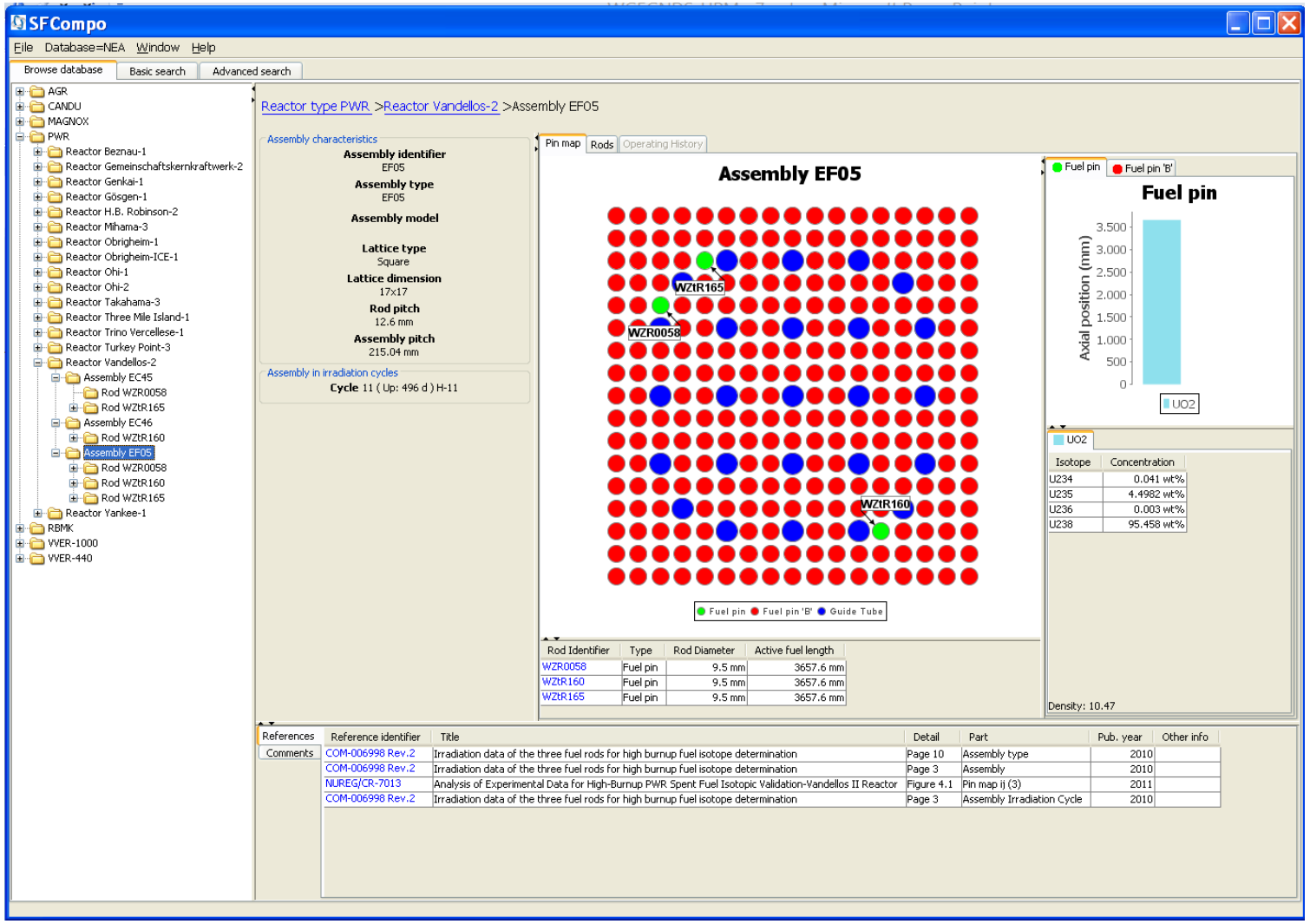
Assembly movement inside the core



Rod movement inside the assembly

11. Vandellós-II (by J. Garrido and P. Romojaro)

- **Java application screenshot**



11. Vandellós-II (by J. Garrido and P. Romojaro)

❑ Problems found and hypotheses

1) Isotope 'Zirlo' has been defined as a new element

2) Pincell 'B' has been added to differentiate the enrichments of each fuel assembly

3) In "Complementary Rod Type DI" the instrumentation tube characteristics are unknown

4) In "Measurement" sheet, the following hypotheses have been assumed:

- 4.1) Isotopes where the corresponding ratio is "less than the specified value", no uncertainty value has been used.
- 4.2) Confidence of the measurements is unknown, so it has been set to 1σ.
- 4.3) In some samples, there was no specified date of the month in which the measurement was taken, so the first day of the month has been chosen as the date to define that situation.
- 4.4) The second experiment performed to determine the ratio of Pu and Am have been considered for samples E58-257 and WZtR160-800.

5) In "Operating history" sheet, some information has been erased owing to an unresolved failure in "Sample" column when the file was imported to the SFCOMPO database. **To be updated.**

- After definition of the new label: "FULL_SAMPLE_REF"
- A "Sample" (e.g. EF05|WZR0058|E58-88) can not be defined in two different Assemblies

11. Vandellós-II (by J. Garrido and P. Romojaro)

"Included in SFCOMPO for all the samples"

Tabla 0.5
Moderator Density and Temperature

	Sample	Cycles 7-8-9	Cycle 10	Cycle 11
	WZtR165			
ρ(g/cm^3)	1	0.7242	0.7348	0.7268
T (ºK)		574.3	569.3	573.2
	WZR0058			
ρ(g/cm^3)	5	0.7258	0.7391	0.7285
T (ºK)		573.7	567.1	572.1
ρ(g/cm^3)	4	0.7263	0.7392	0.7290
T (ºK)		573.2	567.1	572.1
ρ(g/cm^3)	3	0.7387	0.7418	0.7421
T (ºK)		567.1	565.4	565.4
ρ(g/cm^3)	2	0.7411	0.7423	0.7446
T (ºK)		566.0	565.4	564.3
ρ(g/cm^3)	1	0.7421	0.7425	0.7456
T (ºK)		565.4	565.4	563.7

Ref. "Irradiation data of the three fuel rods for high burnup fuel isotope determination". ENUSA Report COM-006998 Rev.2, 2010-12-02

11. Vandellós-II (by J. Garrido and P. Romojaro)

❑ References

Complementary reactor DI	: Ref. 1 page 10.	Rod axial zone	: Ref. 1 page 10
Assembly type	: Ref. 1 pages 3 and 10.	Pin map ij	: Ref. 3 page 19
Rod type	: Ref. 1 page 10	Sample	: Ref. 1 pp. 6, Ref. 4 pp. 4 and Ref. 5 pp.5
Complementary Rod Type	: Ref. 1 page 10	Measurement	: Ref. 6 pages 6-9 and Ref. 5 pages 18-25
Rod	: Ref. 1 page 3	Reactor irradiation cycle	: Ref. 1 page 2
Compound	: Ref. 2 pp.6, Ref. 3 pp.21	Assembly irradiation cycle	: Ref. 1 page 3
Compound composition	: Ref. 1 pages 6 and 10	Operating history	: Ref. 1 pages 4, 9, 11 and 12

[1] QUECEDO M., Irradiation data of the three fuel rods for high burnup fuel isotope determination. ENUSA Report COM-006998 Rev.2, 2010-12-02

[2] ZWICKY H-U, Additional Nuclide Analysis on Vandellós Fuel: Re-evaluation of Data from Gamma Scanning of Rods WZR0058 and WZtR165. Studsvik Nuclear AB N-06/217 Rev. 1, 2008-04-25

[3] ILAS G, GAULD I C, Analysis of Experimental Data for High-Burnup PWR Spent Fuel Isotopic Validation-Vandellos II Reactor. U.S.NRC NUREG/CR-7013, 2011-01

[4] ZWICKY H-U, LOW J, Fuel Pellet Isotopic Analyses of Vandellós 2 Rods WZtR165 and WZR0058. Studsvik Report N(H)-03/069 Rev. 1,, 2008-04-25

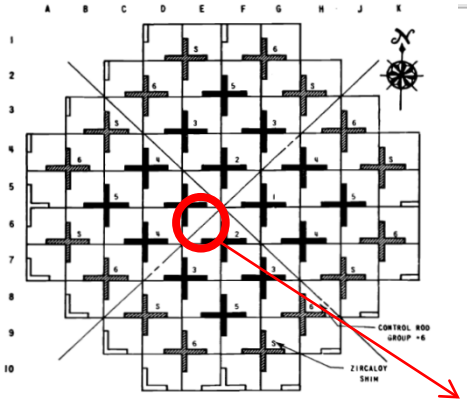
[5] ZWICKY H-U, LOW J, GRANFORS M., Additional Fuel Pellet Isotopic Analyses of Vandellós 2 Rods WZtR160 and WZR0058. Studsvik Report N(H)-07/140 Rev.1, 2010-02-10

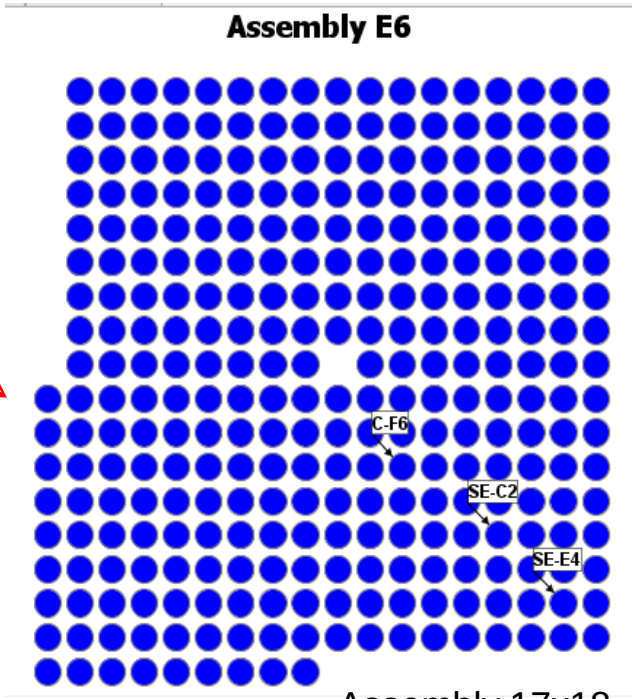
[6] ZWICKY H-U, LOW J, Fuel Pellet Isotopic Analyses of Vandellós 2 Rods WZtR165 and WZR0058, Complementary Report. Studsvik Report N-04/135 Rev. 1, 2008-04-25

12. Yankee (by R. Rey and A. Jiménez)

❑ Reactor and samples description

Yankee Core follow program was supported jointly by the Westinghouse Electric Corporation and the Yankee Atomic Electric Company. It was an 100 MWe experimental reactor. The analyzed samples belong to the assembly that occupied E6 position during cycles I, II and IV.





Assembly 17x18

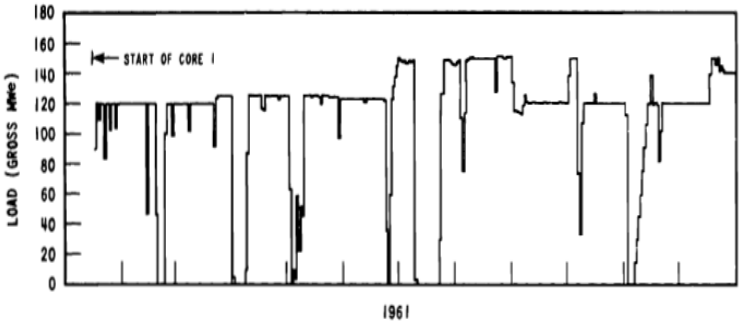
They were captured **9 samples from 3 rod positions**: rod C-F6 (5 samples), rod SE-C2 (2 samples) and rod SE-E4 (2 samples).

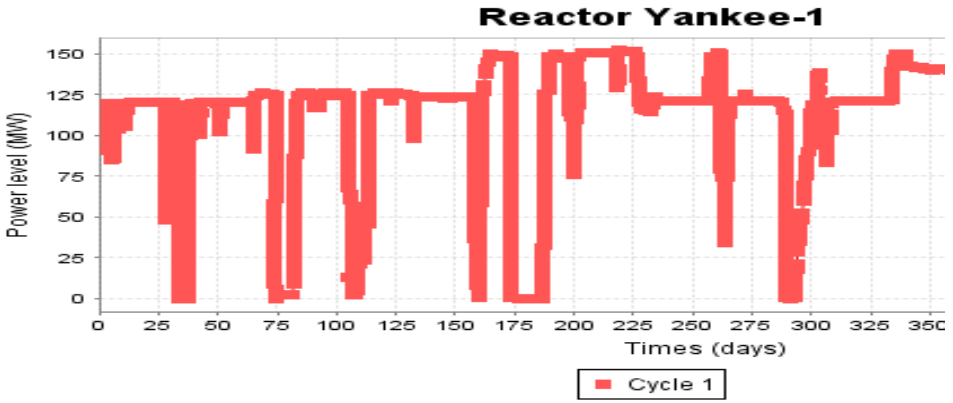
Among C-F6 samples, two of them (T-177 and N-26) are measures of an only one sample, making up to an interlaboratory crosscheck analyses

12. Yankee (by R. Rey and A. Jiménez)

❑ Problems and remarks

- It was necessary to introduce Pu-236 atomic weight in data sheet
- Two rod pitch data in ref. : 0.422 and 0.456. That is because the greatest one belongs to rods aligned with control vanes to permit clearance for control blades. Only introduced the smallest one in SFCOMPO
- The information in references for measurements uncertainties is quite limited. Only uncertainties for Pu-236, Pu-238 and Cs-137 measurements are accurately specified. However, uncertainties of main U and Pu chains are not specified. It is only indicated that uncertainties are located between 0.2 and 0.9 %
- Power level data were captured using an application for extracting points from a chart





❑ Main References

[1] J. Jedruch and R. J. Nodvick: "Experimentally determined burnup and spent fuel composition of Yankee Core I" (WCAP- 6071), July 1965

[2] R. J. Nodvick and et al.: "Supplementary report on evaluation of mass spectrometric and radiochemical analyses of Yankee Core I spent fuel, including isotopes of elements thorium through curium" (WCAP- 6086), August 1969

III. Summary and conclusions

- UPM contribution to SFCOMPO: 12 PWRs-*"Spent Fuel Data Compilations"*
- UPM team as SFCOMPO "beta testing" to check "Tool functionalities"
- Feedbacks and needs are documented
- Future work:
  - Additional "*Spent Fuel Data Compilations"*
  - Modelization of some BWR or PWR compilation: SCALE or MCNP

Acknowledgements

NEA Data Bank support under contract #400027669/500014907, May-July 2013

UPM Students: *A. Burgos, L. Cevallos, P. Díaz, I. Fernández, A. García, I. García, M. García, J. Garrido, C. Israelsson, A. Jiménez, A. López, G. López, E. Morgado, R. Pérez, R. Ruiz, A. Sabater, R. Rey, P. Romojaro, A. Uruburu*

“UPM team”